U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns

Date: 8/21/98

Initiated by: AAS-100

AC No: 150/5220-22

Change:

1. PURPOSE. This advisory circular (AC) contains standards for the planning, design, and installation of Engineered Materials Arresting Systems (EMAS) in runway safety areas. Engineered Materials means high energy absorbing materials of selected strength, which will reliably and predictably crush under the weight of an aircraft.

2. BACKGROUND. Aircraft can and do overrun the ends of runways, sometimes with disastrous results. An overrun occurs when an aircraft passes beyond the end of a runway during an aborted takeoff or while landing. The majority of such overruns by air carrier aircraft come to rest within 1000 feet of the runway end and between the extended edges of the runway. Data on aircraft overruns over a 12-year period from 1975 to 1987 indicate that a large majority of all overruns (approximately 90%) occur at exit speeds of 70 knots or less (Reference 7, Appendix 2). In order to minimize the hazards of overruns, the Federal Aviation Administration (FAA) incorporated into airport design standards the concept of a safety area beyond the runway end. To meet the standards, the safety area must be capable, under normal (dry) conditions, of supporting aircraft that overrun the runway without causing structural damage to the aircraft or injury to its occupants. Besides enhancing airport safety, the safety area provides greater accessibility for emergency equipment after an overrun incident. There are many runways, particularly those constructed prior to the adoption of the safety area standards, where natural obstacles (bodies of water or sharp drop-offs), local development (roads and railroads), or environmental constraints (wetland encroachment), make the construction of a standard safety area impracticable. There have been accidents at some of these airports where the ability to stop an overrunning aircraft within the runway safety area would have prevented major damage to aircraft and injuries to passengers. Recognizing the difficulties associated with achieving a standard safety area at all airports, the FAA undertook research programs on the use of various materials for arresting systems and, in conjunction with industry, conducted a series of field tests utilizing an instrumented Boeing 727 aircraft. As a result of the data obtained from these test programs, the Port Authority of New York and New Jersey (PANY/NJ), in 1997, installed an EMAS comprised of cellular cement on the Runway 4R safety area at John F. Kennedy International Airport. This prototype system is being monitored to provide information on system longevity.

3. APPLICATION. At some airports, reconstruction of a runway requires its safety areas to be brought up to current standards to the extent practicable. Of course, conformance with current standards is desirable at all airports, even when not required by regulation. Occasionally, however, it may not be practicable to achieve a standard safety area as specified in Tables 3-1, 3-2, and 3-3 of AC 150/5300-13, *Airport Design*. In these situations, Appendix 14, *Declared Distances*, of that AC provides an alternative means of enhancing safety. The declared distance alternative allows an airport owner to declare what portions of an operational runway are available to satisfy the aircraft's accelerate-stop and landing distance requirements, with runway beyond these “declared distances” available as runway safety area. However, the use of declared distances at some airports may result in the inability to accommodate aircraft that are currently in use at that airport. In such a situation, installing an EMAS may be another way of enhancing safety. An EMAS is **NOT** a substitute for, nor equivalent to, any length or width of runway safety area and does not affect declared distance calculations. An EMAS is also not intended to meet the definition of a stopway as provided in AC 150/5300-13.

The guidelines and standards contained herein are recommended by the FAA for the design of EMAS. This AC is not mandatory and does not constitute a regulation. It is issued for guidance purposes and to outline a method of compliance. One may elect to follow an alternate method, provided it is also found by the Federal Aviation Administration (FAA) to be an acceptable means of complying with Title 14, Code of Federal Regulations (CFR), Chapter I, FAA. Therefore, mandatory terms such as "shall" or "must" used herein apply only to those who seek to demonstrate compliance by use of the specific method described by this AC, or for those for whom the use of these guidelines is mandatory, such as those installing an EMAS funded under Federal grant assistance programs.

4. RELATED READING MATERIAL. Appendix 2 contains a listing of documents with supplemental material relating to EMAS. These documents contain certain information on materials evaluated, as well as design, construction, and testing procedures utilized to date. Testing and data previously generated under FAA studies referenced in Appendix 2 may be used as input to an EMAS design without further justification.

5. PLANNING CHARTS. The purpose of Figures A1-1 through A1-4 is to allow a preliminary analysis, providing sufficient information to determine whether to proceed with a detailed engineering design of an optimum EMAS installation. They are intended to be used as a preliminary screening tool only. They are not sufficient for final design, which must be customized for each installation. The charts illustrate estimated EMAS stopping distance capabilities for various aircraft types. The design used in each chart is optimized specifically for the aircraft noted on the chart and assumes the availability of brakes and reverse thrust. It should be noted that the absence of either would result in longer stopping distances.

a. Example 1. Assume a candidate runway has a runway safety area that extends 500 feet beyond the end of the runway and the design aircraft is a DC-9 (or similar). Figure A1-1 shows that an EMAS 500 feet in length (including a 100’ jet blast buffer) is capable of stopping a DC-9 within the confines of the system at runway exit speeds of up to 94 knots.

b. Example 2. Assume the same runway safety area but assume the design aircraft is a DC-10 (or similar). Figure A1-3 shows an EMAS of the same length, but designed for larger aircraft, can stop the DC-10 within the confines of the system at runway exit speeds of up to 72 knots.

6. SYSTEM DESIGN REQUIREMENTS. For purposes of design, the EMAS can be considered fixed by its function and frangible since it is designed to fail at a specified impact load. Therefore, an EMAS is not considered an obstruction under 14 CFR Part 77, *Objects Affecting Navigable Airspace*. The following system design requirements shall prevail for all EMAS installations.

a. Concept. An EMAS is designed to stop an overrunning aircraft by exerting predictable deceleration forces on its landing gear as the EMAS material crushes. It must be designed to minimize the potential for structural damage to aircraft, since such damage could result in injuries to passengers and/or affect the predictability of deceleration forces.

b. Location. An EMAS is located beyond the end of the runway, centered on the extended runway centerline. It will usually begin at some distance from the end of the runway to avoid damage due to jet blast and short landings (Figure 1). This distance will vary depending on the available area and the EMAS materials.

c. Design Method. An EMAS design shall be supported by a validated design method, which can predict the performance of the system. The design aircraft is defined as that aircraft using the associated runway that imposes the greatest demand upon the EMAS. To the extent practicable, however, the EMAS design should consider the range of aircraft expected to operate on the runway. In some instances, this may be preferable to optimizing the EMAS for the design aircraft. The design method shall be derived from field or laboratory tests. Testing may be based on passage of either an actual aircraft or equivalent single wheel load through a test bed. The design must consider multiple aircraft parameters, including but not necessarily limited to allowable aircraft gear loads, gear configuration, tire contact pressure, aircraft center of gravity, and aircraft speed. The model must calculate imposed aircraft gear loads, g-forces on aircraft occupants, deceleration rates, and stopping distances within the arresting system. Any rebound of the crushed material that may serve to lessen its effectiveness must be considered.

d. Operation. The EMAS shall be a passive system.

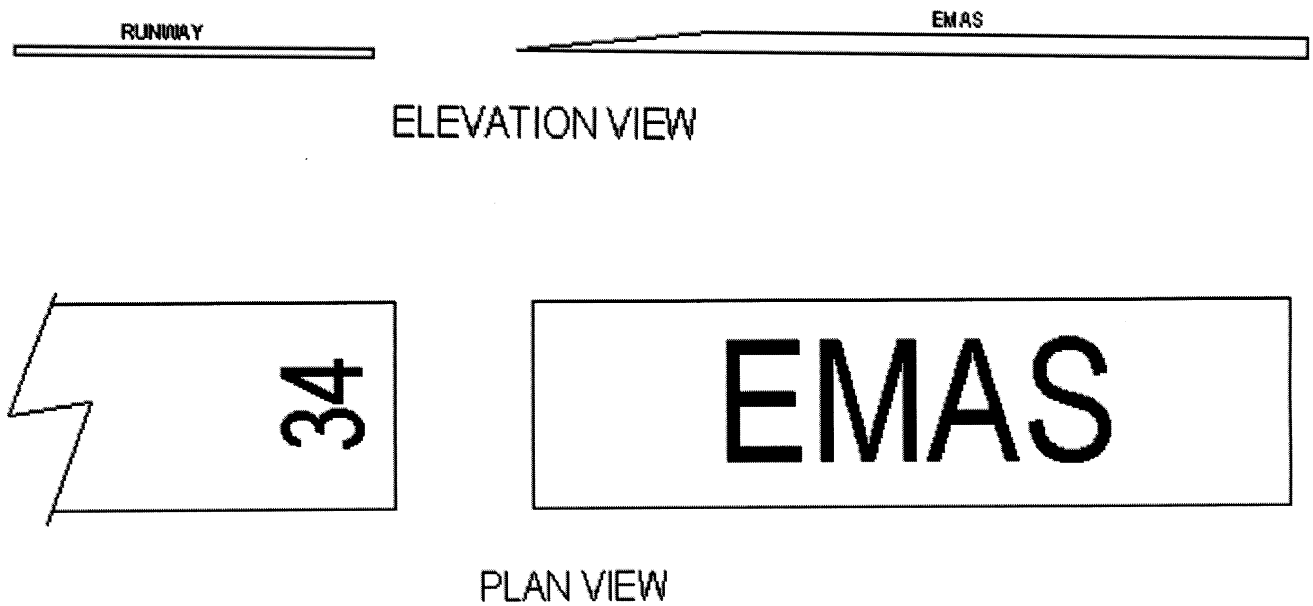

Figure 1. Typical EMAS (Not to Scale)

e. Width. The minimum width of the EMAS shall be the width of the runway (plus any sloped area as necessary – see paragraph 6.h below).

f. Base. The EMAS shall be constructed on a surface capable of supporting the occasional passage of the critical design aircraft using the runway and fully loaded Aircraft Rescue and Fire Fighting (ARFF) vehicles without deformation of the base surface or structural damage to the aircraft or vehicles. It shall be designed to perform satisfactorily under all local weather, temperature, and soil conditions. It shall provide sufficient support to facilitate removal of the aircraft from the EMAS. Full strength runway pavement is not required.

g. Entrance Speed. To the maximum extent possible within the available safety area, the EMAS shall be designed to decelerate all air carrier aircraft expected to use the runway at exit speeds of 70 knots or less without imposing loads that exceed the aircraft's design limits, causing major structural damage to the aircraft, or imposing excessive forces on its occupants. For design purposes, it shall be assumed that the aircraft has all of its landing gear in full contact with the runway and is traveling within the confines of the runway and parallel to the runway centerline.

h. Aircraft Evacuation. The EMAS shall be designed to enable safe ingress and egress as well as movement of ARFF equipment (not necessarily without damage to the EMAS) operating during an emergency. If the EMAS is to be built above existing grade, sloped areas sufficient to allow the entrance of ARFF vehicles from the front and sides must be provided. Provision for access from the back of the EMAS may be provided if desirable, but will result in a shorter effective length. Maximum slopes should be based on the EMAS material and performance characteristics of the airport's ARFF equipment.

i. Maintenance Access. The EMAS shall be capable of supporting regular pedestrian traffic for the purposes of maintenance of the arresting material and co-located navigation aids without surface damage. An EMAS is not intended to support vehicular traffic for maintenance purposes.

j. Undershoots. The EMAS shall be designed so as not to cause control problems for aircraft undershoots touching down in the arresting system. Fulfillment of this requirement may be based solely on flight simulator tests. Materials of density and strength greater than those shown by flight simulator tests not to cause control problems for aircraft undershoots will be deemed acceptable.

k. Navigation Aids. The EMAS shall be constructed to accommodate approach lighting structures and other approved facilities within its boundaries. It shall not cause visual or electronic interference with any air navigation aids. All navigation aids within the EMAS must be frangible as required by 14 CFR Part 139, *Certification and*

Operations: Land Airports Serving Certain Air Carriers. To meet the intent of this regulation, approach light standards must be designed to fail at two points. The first point of frangibility shall be zero to three inches above the top of the EMAS. The second point of frangibility shall be zero to three inches above the expected residual depth of the EMAS after passage of the design aircraft.

l. Drainage. The EMAS shall be designed such that water will not accumulate on its surface or any portion of the runway or runway safety area.

m. Jet Blast. The EMAS shall be designed and constructed so that it will not be damaged by expected jet blast.

n. Repair. The EMAS must be designed to be repaired to a usable condition within 45 days of use by the design aircraft at the design entrance speed. It should be noted that this is a design requirement only – not an operational requirement.

7. MATERIAL QUALIFICATION. The material comprising the EMAS shall have the following requirements and characteristics:

a. Material Strength and Deformation Requirements. Materials must meet a force vs. deformation profile within limits having been shown to assure uniform crushing characteristics, and therefore, predictable response to an aircraft entering the arresting system.

b. Material Characteristics. The materials comprising the EMAS must:

(1) Be water-resistant to the extent that the presence of water does not affect system performance.

(2) Not attract vermin, birds, or other creatures.

(3) Be non-sparking.

(4) Be non-flammable.

(5) Not promote combustion.

(6) Not emit toxic fumes or malodorous fumes in a fire environment after installation.

(7) Not support unintended plant growth with proper treatment.

(8) Have constant strength and density characteristics during all climatic conditions within a temperature range appropriate for the locale as specified by the airport owner.

(9) Be resistant to deterioration due to:

(a) Salt.

(b) Typical aircraft and runway deicing fluids.

(c) Aircraft fuels, hydraulic fluids, and lubricating oils.

(d) Sunlight.

(e) Water.

(f) Freeze/thaw, if installed where freezing is possible.

(g) Blowing sand.

8. DESIGN PROPOSAL SUBMITTAL. The EMAS design shall be submitted to the FAA, Office of Airport Safety and Standards, through the responsible FAA Airports Regional or District Office, for review and approval and shall be certified as meeting all the requirements of this AC. The submittal shall include all design assumptions and data utilized in its development as well as proposed construction procedures and techniques.

9. INSTALLATION.

a. Material Conformance Requirements. A material sampling and testing program shall be established to verify that all materials are in conformance with the previously qualified force vs. deformation profile/limits. The sampling and testing program must be submitted to and approved by the FAA, Office of Airport Safety and Standards. Materials failing to meet requirements based on the testing program shall not be used.

b. Construction. A quality assurance program, submitted to and approved by the FAA, Office of Airport Safety and Standards, shall be implemented to ensure that construction is in accordance with the approved design.

10. MARKING. An EMAS is marked as an area unusable for landing, takeoff, and taxiing with yellow chevrons in accordance with AC 150/5340-1, *Standards for Airport Markings.*

11. MAINTENANCE. An inspection and maintenance program, submitted to and approved by the FAA, Office of Airport Safety and Standards, shall be established and carried out by the airport sponsor to ensure original specified density and strength are maintained throughout the operating life of the EMAS. The program shall include any necessary procedures for preventive maintenance and unscheduled repairs, particularly to weatherproofing layers. Airport personnel must be notified that the EMAS is designed to fail under load and that precautions should be taken when activities require personnel to be on, or vehicles and personnel to be near, the EMAS.

12. AIRCRAFT RESCUE AND FIRE FIGHTING (ARFF).

a. Access. As required by paragraph 6.h, an EMAS is capable of supporting typical ARFF equipment. However, as the sides of the system are typically steeply sloped, and the system will be severely rutted after an aircraft arrestment, ARFF vehicles so equipped should be shifted into all-wheel-drive prior to entering and maneuvering upon an EMAS.

b. Tactics. Any fire present after the arrestment of an aircraft will be three-dimensional due to the rutting and breakup of the EMAS material. A dual-agent attack and/or other tactics appropriate to this type of fire should be employed.

13. NOTIFICATION. Upon installation of an EMAS, its length, width, and location shall be included as a remark in the Airport/Facility Directory. The following is an example of a typical entry:

"Engineered Materials Arresting System, 400'L x 150'W, located at departure end of runway 16."

DAVID L. BENNETT

Director of Airport Safety and Standards

APPENDIX 1 – PLANNING CHARTS.

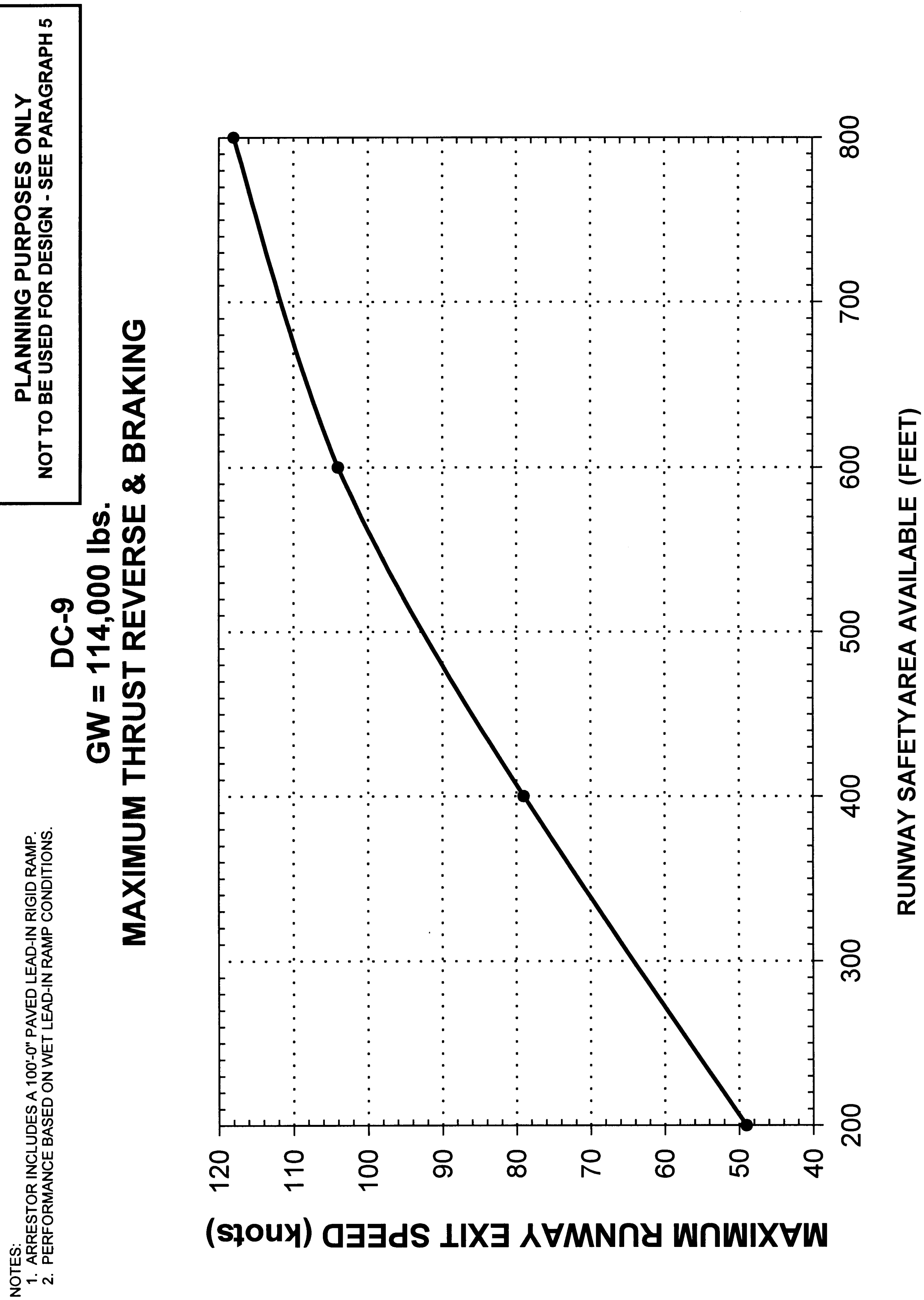

FIGURE A1-1

PLANNING PURPOSES ONLY
NOT TO BE USED FOR DESIGN - SEE PARAGRAPH 5

B727-200
GW = 209,000 lbs.
MAXIMUM THRUST REVERSE & BRAKING

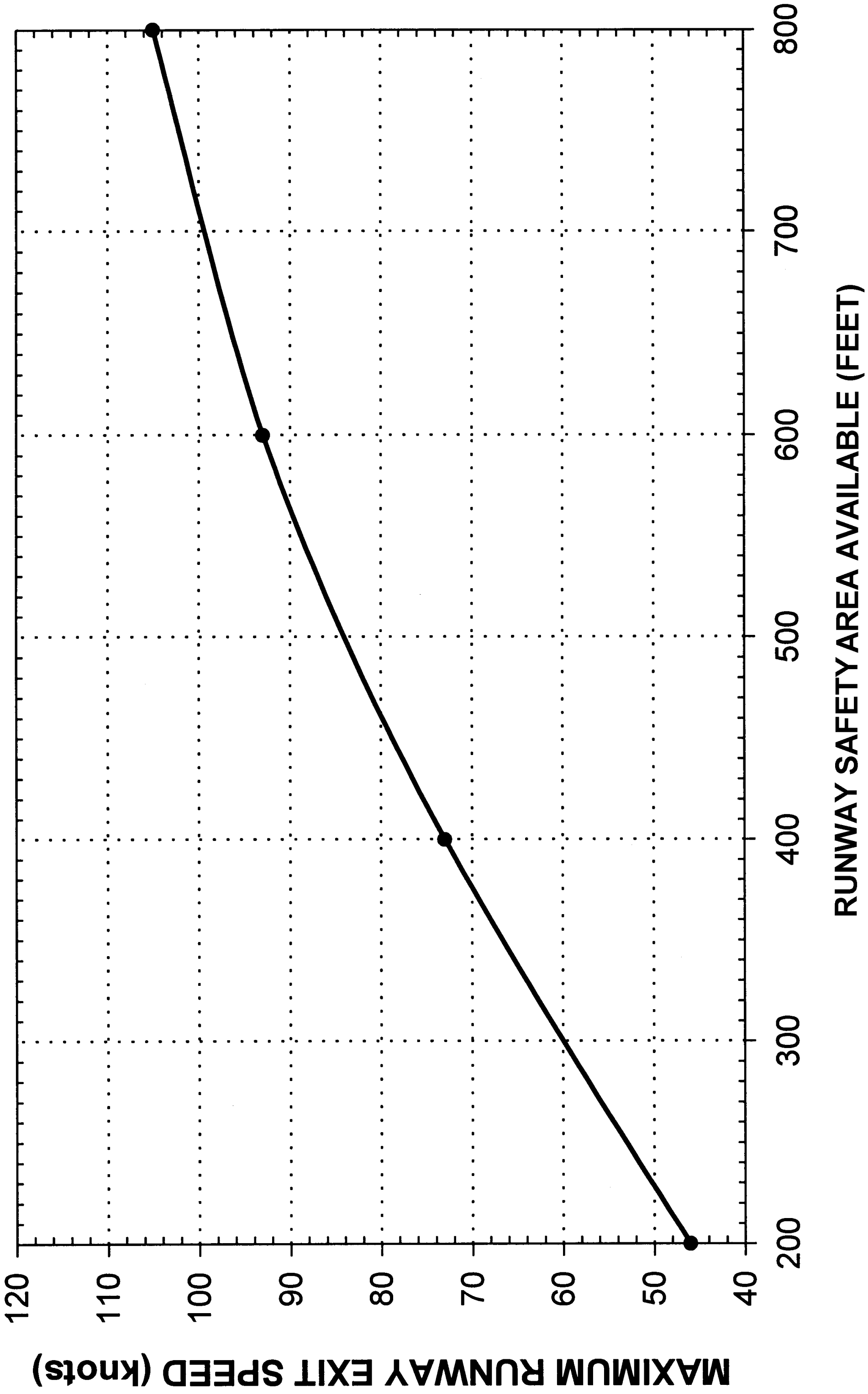

FIGURE A1-2

NOTES:
1. ARRESTOR INCLUDES A 100'-0" PAVED LEAD-IN RIGID RAMP.
2. PERFORMANCE BASED ON WET LEAD-IN RAMP CONDITIONS.

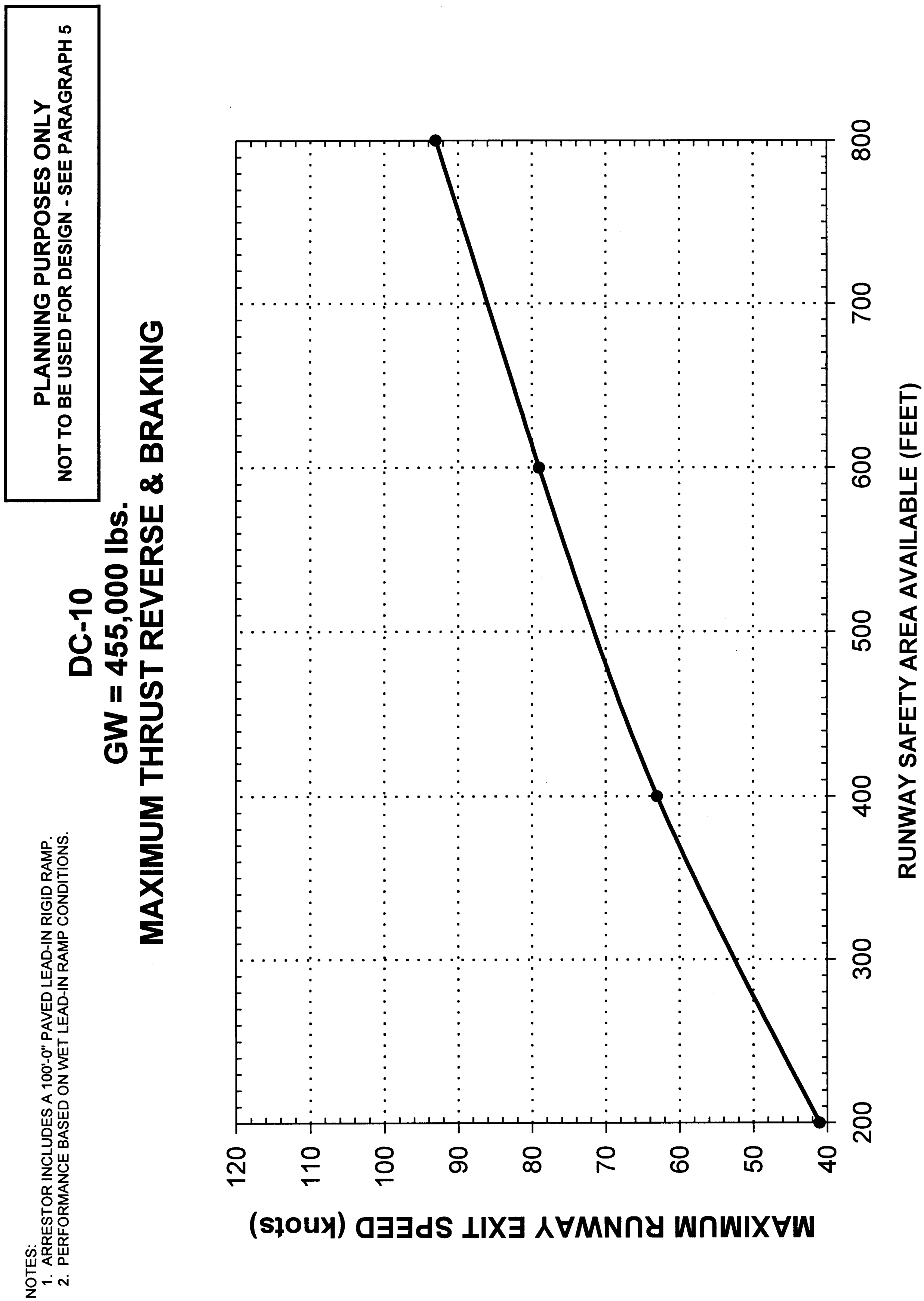
PLANNING PURPOSES ONLY
NOT TO BE USED FOR DESIGN - SEE PARAGRAPH 5
DC-10
GW = 455,000 lbs.
MAXIMUM THRUST REVERSE & BRAKING
NOTES:
1. ARRESTOR INCLUDES A 100'-0" PAVED LEAD-IN RIGID RAMP.
2. PERFORMANCE BASED ON WET LEAD-IN RAMP CONDITIONS.
MAXIMUM RUNWAY EXIT SPEED (knots)
120
110
100
90
80
70
60
50
40
200
300
400
500
600
700
800
RUNWAY SAFETY AREA AVAILABLE (FEET)

FIGURE A1-3

PLANNING PURPOSES ONLY
NOT TO BE USED FOR DESIGN - SEE PARAGRAPH 5

B747
GW = 820,000 lbs.
MAXIMUM THRUST REVERSE & BRAKING

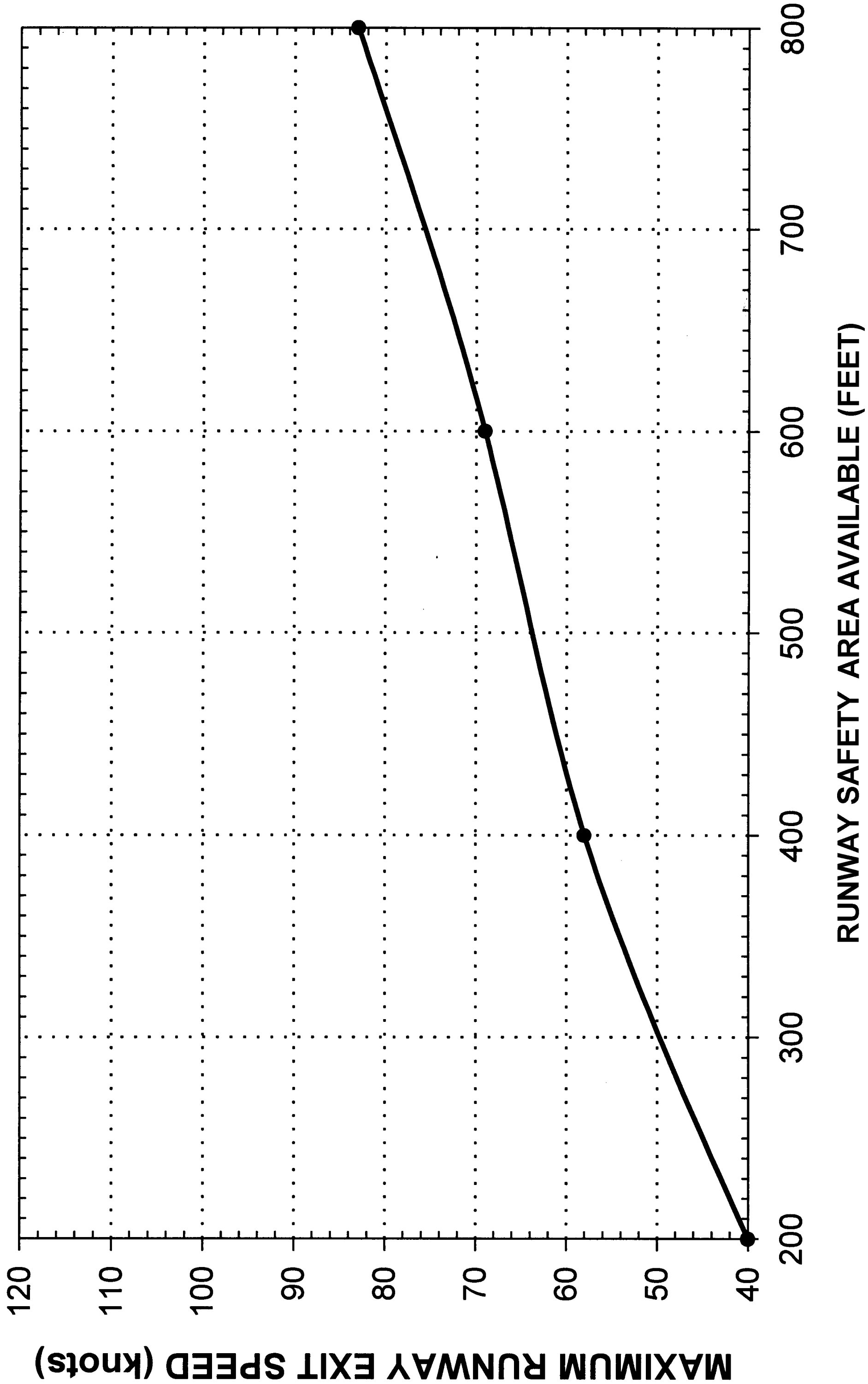

FIGURE A1-4

NOTES:
1. ARRESTOR INCLUDES A 100'-0" PAVED LEAD-IN RIGID RAMP.
2. PERFORMANCE BASED ON WET LEAD-IN RAMP CONDITIONS.

APPENDIX 2. RELATED READING MATERIAL.

This appendix contains a listing of documents with supplemental material relating to the subject of EMAS. These documents contain certain information on materials evaluated as well as design, construction, and testing procedures utilized to date. These publications may be obtained from the National Technical Information Service (NTIS), Springfield, VA 22151.

1. DOT/FAA/PM-87/27, *Soft Ground Arresting Systems*, Final Report-Sept. 1986 - Aug. 1987, published Aug. 1987 by R.F. Cook, Universal Energy Systems, Inc., Dayton, OH.

2. 2. DOT/FAA/CT-93/4, *Soft Ground Arresting Systems for Commercial Aircraft* **-** Interim Report-Feb. 1993 by Robert Cook.

3. DOT/FAA/CT-93/80, *Soft Ground Arresting Systems for Airports* **-** Final Report **-** Dec. 1993 by Jim White, Satish K. Agrawal, and Robert Cook.

4. Draft Report **-** DOT/FAA/CT-95, *Preliminary Soft Ground Arrestor Design for JFK International Airport* **-** March 1995.

5. Draft Test Report **-** *Soft Ground Arresting System Using Cellular Concrete* **-** Nov. 1994.

6. DOT/FAA/AOV 90-1 **-** *Location of Commercial Aircraft Accidents/Incidents Relative to Runways*, July1990.

7. UDR-TR-88-07, Cook, R.F., *Evaluation of a Foam Arrestor Bed for Aircraft Safety Overrun Areas*, University of Dayton Research Institute, Dayton, Ohio. 1988.